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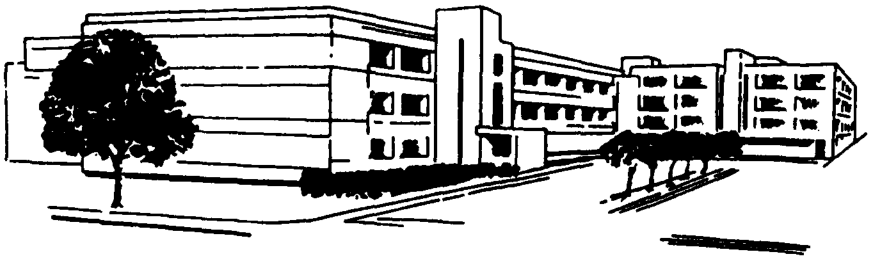
INSTITUTE REPORT NO. 455

Results Of A Pilot Study: Target Identification Using Computer Visual Simulation Of Laser-Induced Contrast Sensitivity Deficits

J.D. Gunzenhauser,
E. Holt,
H. Zwick
and
J.W. Molchany

Division of Ocular Hazards

September 1990



LETTERMAN ARMY INSTITUTE OF RESEARCH PRESIDIO OF SAN FRANCISCO CALIFORNIA 94129

Results of A Pilot Study: Target Identification Using Computer Visual Simulation Of Laser-Induced Contrast Sensitivity Deficits, J.D. Gunzenhauser, E. Holt, H. Zwick and J.W. Molchany

Human Subjects participated in these studies after giving their free and informed voluntary consent. Investigators adhered to AR 70-25 and USAMRDC Reg 50-25 on the use of volunteers in research.

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Donald G. Corby — 27 Nov 90

DONALD G. CORBY — **(date)**
COL, MC
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UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION: UNCLASSIFIED

1b. RESTRICTIVE MARKINGS:

2a. SECURITY CLASSIFICATION AUTHORITY:

2b. DECLASSIFICATION / DOWNGRADING SCHEDULE:

3. DISTRIBUTION / AVAILABILITY OF REPORT: Unlimited Distribution

4. PERFORMING ORGANIZATION REPORT NUMBER(S): INSTITUTE REPORT NO. 455

5. MONITORING ORGANIZATION REPORT NUMBER(S):

6a. NAME OF PERFORMING ORGANIZATION: Letterman Army Institute of Research

6b. OFFICE SYMBOL *(If applicable)*:

7a. NAME OF MONITORING ORGANIZATION: United States Army Medical Research and Development Command

6c. ADDRESS *(City, State, and ZIP Code)*:
Letterman Army Institute of Research
Division of Ocular Hazards
Presidio of San Francisco, CA 94129-6800

7b. ADDRESS *(City, State, and ZIP Code)*:
Fort Detrick
Frederick, MD 21701-5012

8a. NAME OF FUNDING / SPONSORING ORGANIZATION:

8b. OFFICE SYMBOL *(If applicable)*:

9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER:

8c. ADDRESS *(City, State, and ZIP Code)*:

10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.

11. TITLE *(Include Security Classification)*: Results of a pilot study: Target identification using computer visual simulation of laser-induced contrast sensitivity deficits.

12. PERSONAL AUTHOR(S): Jeffrey D. Gunzenhauser, Eric F. Holt, Harry Zwick, Jerome W. Molchany, and George R. Mastroianni.

13a. TYPE OF REPORT: Laboratory Report

13b. TIME COVERED: FROM Jun 90 TO Jun 90

14. DATE OF REPORT *(Year, Month, Day)*: 90, September

15. PAGE COUNT: 19

16. SUPPLEMENTARY NOTATION:

17. COSATI CODES

FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS *(Continue on reverse if necessary and identify by block number)*: Eye injuries, laser injuries, contrast sensitivity, computer simulation

19. ABSTRACT *(Continue on reverse if necessary and identify by block number)*

In a pilot study we developed a set of computerized military-relevant images and used a subset of these in a target recognition performance study. Images were created by digitizing video images of four model tanks placed in a simulated terrain environment. Images varied by country of tank, orientation of the tank, and viewing distance. Each image was passed through an empirically derived filter to simulate changes in contrast sensitivity following acute laser exposure. A subset of the original images and their corresponding "filtered" images were used in a human performance study. Six subjects were initially trained to recognize only the unfiltered images. Image-processing software and hardware were used to present and modify the contrast of images according to a standardized rate and sequence. During the study, images were presented in pairs and subjects were forced to choose the first image that became recognizable. Filtering of the image was the strongest predictor of observed variability in the response times. Based upon these preliminary results, we conclude that existing image-processing hardware and software provide an excellent (continued)

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT: ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS

21. ABSTRACT SECURITY CLASSIFICATION: UNCLASSIFIED

22a. NAME OF RESPONSIBLE INDIVIDUAL: Donald G. Corby, COL, MC

22b. TELEPHONE *(Include Area Code)*: (415) 561-6300

22c. OFFICE SYMBOL: SGRD-ULE-Z

DD Form 1473, JUN 86 — Previous editions are obsolete. — SECURITY CLASSIFICATION OF THIS PAGE

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Abstract

In a pilot study we developed a set of computerized military-relevant images and used a subset of these in a target recognition performance study. Images were created by digitizing video images of four different model tanks placed in a simulated terrain environment. Images varied by country of tank, orientation of the tank, and viewing distance. Each image was passed through an empirically derived filter to simulate changes in contrast sensitivity following acute laser exposure. A subset of the original images and their corresponding "filtered" images were used in a human performance study. Six subjects were initially trained to recognize only the unfiltered images. Image processing software and hardware were used to present and modify the contrast of images according to a standardized rate and sequence. During the testing images were presented in pairs and subjects were forced to choose the first image that became recognizable. Filtering of the image was the strongest predictor of observed variability in the response times. Based upon these preliminary results, we conclude that existing image-processing hardware and software provide an excellent opportunity for human visual performance testing and will facilitate extensive research in the field of visual performance.

Results of a pilot study: Target identification using computer visual simulation of laser-induced contrast sensitivity deficits.

Jeffrey D. Gunzenhauser, Eric F. Holt, Harry Zwick,
Jerome W. Molchany, and George R. Mastroianni.

Introduction

Exposure of the human retina to laser light may result in a variety of clinical outcomes. These range from temporary performance-decrementing phenomena (e.g., glare or flashblindness) to catastrophic, blinding events (e.g., sub-retinal or vitreous hemorrhage). Depending upon the degree of energy imparted to the retina, exposed individuals may suffer losses in visual function which may last for minutes or for a lifetime. Analysis of the nature of these decrements would be of great value not only in predicting performance of specific military tasks, but also in establishing criteria for the diagnosis and management of laser-exposed individuals.

Studies in non-human primates which have been exposed to specific frequencies and energies of laser light have demonstrated a consistent change in spatial vision. Specifically, there is a spatial-frequency dependent decrement in visual acuity. Such decrements may be temporary, last for a period of minutes, or may last for longer lengths of time. Animal studies upon which such results are based have been limited to the measurement of visual acuity as the major outcome variable. Training of animals to search for and recognize high acuity targets (Landolt rings) is a resource-intensive process, requiring many months of training for each animal and involving the potential of permanent eye injury with repeated exposures to laser light at or near the MPE or ED-50. In addition, complex aspects of visual function which accompany identification, recognition, and tracking tasks in humans cannot be measured in animal models. Clearly, the use of humans in trials similar to those in which non-human primates have been used would pose significant and unacceptable risks. Therefore, the use of other moc 's to measure performance would be of great value in assessing the effect of laser e: ,osure on visual function.

Mastroianni and Zwick have developed an alternate technique for measuring performance aspects of target-detection by using a computer simulation of visual decrements associated with laser exposure.[1] In this simulation, an empirically derived filter (based upon the above-mentioned primate studies) is used to create an image which simulates a spatial-frequency dependent decrement in visual acuity. Using two-dimensional fast Fourier transformation (FFT), a normal image is rapidly processed to reconstruct the image as it may appear to the laser-injured eye. The same technology which can simulate injury can also be used to simulate in real-time other real-world phenomena. An example of an acuity-determining variable which can easily be simulated is the degree of contrast present in target features or between the target and the background. The entire image-processing system, therefore, can simulate not only the laser eye injury itself but also a range of environmental conditions which may affect visual performance. Such a system lends itself for measuring human performance under a range of simulated conditions.

While image-processing technology has existed for a number of years, its utilization has largely been restricted due to size and cost restraints. The hardware and software necessary to conduct realistic human studies has only recently become available to us. This report summarizes the results of a pilot study. As described in detail below, the

purposes of this study were two-fold. First, we developed a library of military-relevant images which will serve as the basis for future work. Second, using a subset of these images we developed and refined a new technique for assessing human performance in target detection.

Methods

<u>Development of military-relevant images</u>.

Scale models of several friendly and threat military tanks were constructed. These included the British Challenger, the US M1 Abrams , the T-74 Soviet Tank, and the Israeli Merkava. The scale for each model was 1:35. All models were spray-painted in a flat tan color.

Video images were recorded of each tank in the terrain-board simulator environment known as "BLASER". All images were taken using a MICRO-TECHNICA M-852 CCD Color Camera. The camera was located at ground level to simulate viewing by an observer located on the ground. Video images were processed and stored on an IBM AT-compatible microcomputer using the Biological Image Processing Package (BLIMP), a product made under contract for the US Army by Delta Technologies, Inc. of Denver, Colorado. A series of images was made of each tank from two distances. Images at the first distance ("near") were taken with the center-of-mass (COM) of the tank located 9 feet 9.5 inches from the camera. At the second distance ("far"), the tank COM was 20 feet 8 inches from the camera. All tanks were placed in the same position so that background terrain features were identical for each image. Scene illumination remained constant throughout the video-recording sessions. Camera settings were identical for images made at the same distance. At each distance, eight (8) video images of each tank were recorded (see Fig. 1). These eight views included: front (0°), left-front oblique (45°), left side (90°), left-rear oblique (135°), rear (180°), right-rear oblique (225°), right side (270°), and right-front oblique (315°). In total, 64 images were recorded under these conditions (4 tanks x 2 distances x 8 orientations). Video images of all four tanks were also recorded simultaneously from each of the following four positions: front (0°), left side (90°), rear (180°), and right side (270°). In addition, numerous images were taken of each tank located in three (3) terrain-camouflage/defilade positions. These camouflage images were not utilized further in this study but have been archived for use in future studies.

<u>Human performance testing of target detection</u>

Of the 16 uncamouflaged images made of each tank, 8 were used in the performance study (Fig. 2). These included 5 from the "near" position and 3 from the "far" position and are hereafter referred to as the near front (0°), far front (0°), near left side (90°), far left side (90°), near rear (180°), far rear (180°), near left-front oblique (45°), and near left-rear oblique (135°) views. Thus 32 (8 views x 4 tanks) of the original 64 images were used in the study. An additional 32 images were created by passing each original image through a filter designed to simulate short term effects of laser exposure. This filter was derived empirically from non-human primate studies in which trained animals of high visual acuity were exposed to threshold levels of laser light. The filter derives from short term loss of spatial-frequency dependent contrast sensitivity. In total, then, 32 "unfiltered" and 32 "filtered" images were used in this study.

Software was written specifically for use in the human performance study. This software was created using the Image Stimulus Language (ISL) of Delta Technologies, Inc. Software modules were written to present images to subjects at a standardized rate and in a specified sequence. Modules were written both to train and test subjects.

Volunteers were recruited from within the Division of Ocular Hazards. All were naive to the content of images prior to entering the study. All had visual acuity correctable to 20/20 or better. Informed consent was obtained from each volunteer.

Each subject participated in both a "Training" and a "Test" session. Each session lasted approximately one hour. The purpose of the training session was to teach each of the participants to recognize each of the 32 unfiltered images with 100% accuracy. Training was conducted in the following manner. Each subject was first shown the four models of the tanks. Key differentiating features of each tank were emphasized. Next, using a single module of ISL software, all unfiltered video images were reviewed on the subject's computer screen. First, the subject was shown the views which contained all four tanks from the front (0°), left side (90°), and rear (180°) orientations. The subject was then subjectively "walked through" each of the eight views of first the British, then the US, then the Soviet, and finally the Israeli tank. After this introduction, the subject was further trained in the following manner. A separate software module was written for each tank view (e.g., one module was written for the near front view, one for the far front view, etc.). In each training module, images of the four tanks as seen in the specified view were presented randomly bv a random number generator included in the ISL. Each image was displayed on the subject 's computer screen for 6 seconds, during which time the subject was instructed to identify the country of origin of the tank. The correct name of the tank was simultaneously displayed on the Controller's screen. If the subject identified the image correctly, he/she was told "correct." If the subject responded incorrectly, the proper response was provided by the Controller. The screen appeared blank for two seconds between each image. Images continued to be presented until the subject had learned to distinguish correctly each of the four tanks. This normally required that each of the four tanks be identified correctly at least twice in a row before completing the module. In all cases, the training module was continued until the subject was satisfied that he/she was entirely familiar with each of the images.

The "Test Session" was conducted in the following manner. The test session was begun not earlier than three hours after the initial training session. For five subjects, the training and test sessions were conducted on the same day. For the other subject, the test session was conducted on the day following the training session. During the test session, the monitor was located at a distance of 1.21 meters from the subject's eyes. Based upon measurements of the image size on the screen, we estimated that this testing environment simulated viewing real tanks through 10-power optics at a range of 490 meters for the large images (near distance) and 1100 meters for the small images (far distance). The test session began by refamiliarizing each subject with the tanks. Models were made available for review. In addition, each subject was permitted to "walk through"

each of the 32 images as presented in the first training module described above. After completion of this walk-through, performance testing was initiated.

Sixteen (16) separate testing modules were conducted. In each module, the subject was tested on his/her ability to distinguish between each of the tanks presented from a particular view. The first 8 modules corresponded with unfiltered images, the last 8 modules, with filtered images. Each module consisted of 10 forced-choice trials. The method for conducting each trial is summarized in Figure 3. In each trial, a pair of images were shown on the screen, one on the left side and one on the right. Initially both images were presented with 0 percent of the contrast of the baseline image (i.e., the image was completely white). Gradually (i.e., as controlled by software), the contrast of both images was increased. The software was written so that 100% of the contrast contained in the original image was reached 25 seconds after starting the trial. The subject was instructed to observe both images on the screen and to state verbally "OK" or "Stop" when either of the two images could be recognized. At this point, the controller signaled the computer to halt the increase in image contrast. The Controller's screen indicated the percent of the contrast of the original image at the time the trial was stopped. After the controller halted the trial, the image pair remained on the screen for an additional 2 seconds, after which the screen would appear blank. During this period, the subject indicated "Left" or "Right" and the country of origin of the tank. The controller used a scoring sheet to track correct and incorrect responses and the percent of original contrast at which the image was recognized. The 10 trials in each testing module corresponded with the 10 unique paired combinations of the four images, and included the combinations in which a particular image was paired with itself. This ensured that each subject was forced to select each of the four tank images during at least one of the trials. Orderings of the pairs and left- and rightsidedness of images were randomized. Randomization was completed prior to the start of the study using a random number generator. The same "random" sequence and sidedness of pairs was observed across subjects.

The percent of the contrast in the original image at which the subject recognized a particular image is described as the "Relative Contrast Threshold." Note that this measure does not reflect an absolute level of contrast, but rather the relative amount of contrast present in the image at the time the subject recognized the target relative to the amount of contrast in the original image. "Average" relative contrast thresholds were estimated by computing the mean of a group of thresholds. Trials in which the participant incorrectly identified an image were excluded from subsequent analyses. An unbalanced analysis of variance (ANOVA) was performed using the General Linear Models (GLM) procedure of SAS (VMS SAS Production Release 5.18, SAS Institute Inc., Cary , NC 27512-8000). The following main effect and interaction terms were included in the model: filter, subject, tank, view, distance, subject*view, subject*distance, tank*view, subject*tank, view*distance, and filter*tank.

Results

Video images were easily created from models placed in the terrain-simulation environment of BLASER. In total, 100 images were created: 68 uncamouflaged and 32 camouflaged. These have been archived for future research projects. A list of all of the images is included as an Appendix to this report.

Six volunteers, three men and three women, were recruited to participate in the pilot study. Three were on active duty in the US Army and three were Department of the Army civilian employees. The time required to train participants to recognize images with high accuracy was short. The training modules in which images were presented randomly were very effective at facilitating learning of the images. Without exception, participants learned to distinguish accurately among the four tanks by the time 20 random images had been presented (i.e., 5 images of each tank) from each view.

The high degree of competency achieved by participants is reflected in the "Accuracy" rows of Tables I and II. Overall, for both unfiltered and filtered images, subjects correctly identified the selected image in 92% of forced choice pairs. While no subject achieved perfect accuracy, the lowest observed performance level was 87.5% (Subject 4, Unfiltered Images).

Figure 4 displays summary results for the various views. Averages have been made across both subjects and tanks. On average, unfiltered images could be detected at between 14 and 19 percent of the original image contrast. Filtered image detection occurred between 21 and 29 percent of the original contrast. In the front and rear views, the near image was detected at a lower average threshold than the far image, but opposite results were obtained for the side view. The observed reverse effect for side views may be attributable to the unavoidable trimming which was required to permit two images to fit side-by-side on the video screen. Truncated portions included most of the gun tube and a small portion of the rear of each tank. In all other views, virtually the entire tank was visible during the forced pair testing.

Figure 5 shows that, on average, the Soviet tank was recognized at a lower relative contrast threshold than other tanks. This is most apparent for filtered images. Among forced choice pairs in which each tank was presented with a tank other than itself, the following selection rates were observed: British: 32.7%, US: 45.6%, Soviet: 77.5%, and Israeli: 44.2%. Thus, according to both relative contrast threshold and selection frequency criteria, Soviet tank images were more easily recognized.

In Figure 6, detailed results are provided of each subject for each of the 16 view-filter conditions. Keep in mind that each point represents the average results of 10 forced-choice pair selections, within which each tank was selected at least once. In general, the range of results for each subject of filtered trials (filled-in symbols) is broader than for unfiltered trials (open symbols). Also, the variability across subjects for any particular viewing condition is comparable to the variability of any particular subject across views (filter-specific). Although not shown, the intra-observer variability for a particular filter-view condition was significantly less than the inter-observer variability.

Table III displays results of the General Linear Models analysis. This is equivalent to a multi-way unbalanced ANOVA, which is the analysis required for this set of data. Each of the five main effect variables (tank, view, distance, filter, and subject) were statistically significant. In addition, six interaction terms prospectively identified as potentially important were also significant. Overall, the model accounts for 60.6% of the observed variability. Nearly half of this explained portion is attributed to the "filter" variable. The importance of inter-subject variation in contributing to observed variability derives not only from the fact that it is the second most important main effect term, but also from the fact that three of the four most significant interaction terms include this variable.

Discussion

The results of this pilot study indicate that existing hardware and software technologies yield high quality image-processing capabilities which can support meaningful human visual performance testing. The images created using scale models in the BLASER environment were regarded by investigators and participants alike to be of exceptional, life-like quality. The fact that the images were created using a gray (i.e., non-color) scale did not detract from their realistic appearance. The precise method of placing each model in a virtually identical position effectively enabled us to produce military-relevant images with desirable visual characteristics. Minute-to-minute fluctuations in environmental conditions which can affect similarity of images produced in the real-world were absent in the methods used in this study. A further advantage of the laboratory environment is the ability to precisely control lighting conditions according to pre-defined parameters. While we did not avail ourselves of defining such parameters during this study, the benefits of this potential in future work should be obvious.

The specific images created in this pilot study have several desirable characteristics. First, there is a clear connection between the images and the important military tasks of target identification and recognition. A key element of our current military posture is the defense of defined borders. This element relies upon the ability of soldiers to recognize friendly and threat systems. The images used in this study are based upon detailed models of currently deployed systems which are likely to be encountered by many of our soldiers. Thus, the military relevance of visual performance tests based upon these images is likely to be evident to non-technical military personnel. Second, the size of the images and the viewing distances which they simulate represent a reasonable real world scenario. Soldiers deployed in observation posts (whether along our current defensive borders or in other military situations) are routinely expected to survey the forward area with 10-power optics for ranges as near as several hundred meters and as far as several kilometers. We calculated that the testing session of this study simulated viewing tanks through 10-power optics at ranges of 490 meters and 1100 meters for near- and far-distance images, respectively. A third desirable characteristic of the images is that they are employable in a performance task wherein the subject is likely to be motivated. In particular, subjects are more prone to perform well in a visual performance test in which they are asked to identify tanks as opposed to circles, squares, or other geometric shapes. Additional environmental stimuli such as the incorporation of subject-used "firing" or target acquisition buttons, the inclusion of auditory cues upon identification or "firing," or the development of a scoring system to tally the subject's progress could all enhance motivation.

The pilot performance study effectively demonstrates the feasibility of conducting a well structured visual performance task using the the image-processing software and hardware. ISL greatly facilitated the manipulation of images for both training and testing purposes. Despite the large file sizes of digitized images, we were able to store all images on one Bernoulli disk (20 MB) and perform the entire study without the necessity of exchanging disks. During the testing phase, the pace was slowed somewhat by the time required for the Bernoulli drive to read the two image files associated with the assigned pair. The use of a faster drive would have enhanced the flow of the testing session. Nonetheless, once the ISL modules were written, control of the system was simple. In total, the controller completed all training and testing sessions by typing only approximately 25 commands. More effective and simpler control of the operation would

have been possible by overlaying the ISL modules with a DOS-based, menu-driven BATCH file. In this way, the controller would have been able to launch the next phase of the session by entering one number rather than typing a two-word command. The real time manipulation of images through FFT processes is a remarkable feature of the current hardware system. In a period of a few seconds, a completely blank screen evolves into a recognizable military vehicle. The ability to modify the speed of the process and to capture data (time and contrast) as the process occurs lends itself to an excellent testing paradigm. Other features of the system include the ability to modify selected portions of the image and to attach peripheral input devices to route the program as it is executed. These and other features will support the development of more complex testing modules.

Despite the pilot nature of this study, the results of the performance testing have significant value. They both provide an objective measurement of our intuitive impressions and suggest areas for further research. The univariate and bivariate analyses of Average Relative Contrast Thresholds support our notions that differences in the tanks, distances, orientations, subjects, and filter conditions affect the recognition thresholds. The unbalanced ANOVA indicates that filtering the image (to simulate a laser injury) had a greater effect upon performance than any other feature. Of note is that differences between subjects was next in importance in affecting performance. Significant interactions between the model variables indicates that visual performance tests inherently involve many complex processes which require thorough and thoughtful analysis.

Several results of the performance testing require specific comment. First, the observation that far, side images were more easily detected than near, side images has at least two possible interpretations. One is that a diminished ability to recognize the near images resulted from trimming the image to fit two images on the screen simultaneously. Some of the participants subjectively commented that they relied upon aspects of the gun tube to identify the tanks, and that truncation eliminated this feature for identifying near side images. Another interpretation is that for near side images, the wealth of detail provides a confusing recognition task for the test participant; whereas, for far side images, the silhouette becomes the most important single feature, a feature that is quickly learned during the training session. This aspect of side view images deserves further analysis in a future study. A second significant finding of the study is that the Soviet tank was more easily recognized than the other tanks. This may have been due to the relatively smaller size of the Soviet tank or perhaps to the distinct profile. In the real world in which all tanks are not simultaneously fixed at equal distances, the apparent size of any particular vehicle may not affect recognition. Again, a future study may easily be designed to test this hypothesis.

Other avenues for future research are apparent as a result of this pilot study. One question deserving serious attention concerns what aspects, if any, of the visual search process facilitate quicker recognition of targets. Are these process-specific aspects target-related or do they apply across a broad range of target recognition tasks? The assessment of this question may be rather complex, but may initially be attempted through the use of an eye-tracking device which records the area where the subject is focusing on the target. A second area where further work should be pursued is in identifying which specific features of targets are most important in target recognition. Again, an eye-tracking device would facilitate answering this question. Alternatively,

selected portions of standard images could be degraded or camouflaged, then compared with undegraded images. A more extensive image library which includes images of other military-relevant targets should be developed to address this issue broadly. Certainly aircraft and other ground-based military systems should be included in the image library. Other specific aspects of target recognition which can and should be assessed using the current system include the role of background contrast and camouflage in target recognition, the affect which position of the turret and other vehicle-based objects may have on performance, and to what degree prior education may enhance performance.

Further development of the current image-processing system will certainly bear many fruits. At a basic science level, we will acquire a more thorough understanding of the factors involved in target recognition and identification. A clearer delineation of the relative role of environmental, ocular, and central nervous system phenomena will hopefully lead to strategies which may enhance performance. Computer simulation of acute laser injuries will aid us in appreciating performance decrements which may be anticipated if such were to occur on the modern battlefield. Further refinement and validation of various testing modalities may lead to the development of tests with diagnostic value in the evaluation of individuals with laser-induced or other types of eye injury. In this context, we may define ranges of normal performance and assess whether a particular individual is able to perform within specified limits. And certainly, there are many insights to be gained and many uses to be realized of which we have no notion at this time.

Reference

1. Mastroianni G and Zwick H. "Detection of targets in spatially filtered images." (Unpublished).

Table I. Relative Contrast Threshold (percent) for Recognition of Unfiltered Images by View of Tank

View	All Subjects	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5	Subject 6
Front Near	14.93	16.60	16.78	19.84	10.62	13.14	13.78
Front Far	16.24	16.96	15.87	23.20	12.97	12.56	16.83
Side Near	14.84	16.78	11.78	14.89	16.20	13.98	15.80
Side Far	14.09	12.82	13.80	17.86	10.91	11.44	17.83
Rear Near	15.94	19.04	15.00	14.96	11.91	12.86	21.40
Rear Far	18.59	25.36	14.96	22.22	15.82	11.58	20.87
Front Oblique	15.81	22.46	12.50	13.80	12.73	13.44	18.20
Rear Oblique	16.93	18.88	13.96	16.70	13.02	15.93	22.94
Average	15.9	18.6	14.3	17.8	12.9	13.1	18.5
Possible Responses:	480	80	80	80	80	80	80
Correct Responses:	442	79	74	71	70	75	73
Accuracy (%):	92.08	98.75	92.50	88.75	87.50	93.75	91.25

Table II. Relative Contrast Threshold **(percent) for Recognition of Filtered Images by View of Tank**

View	All Subjects	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5	Subject 6
Front Near	21.54	21.54	23.36	22.19	19.90	18.20	23.28
Front Far	25.37	32.31	25.20	32.88	22.20	16.02	25.02
Side Near	23.29	24.00	20.29	23.58	20.53	19.53	30.88
Side Far	21.27	18.74	24.42	26.02	16.78	16.47	26.80
Rear Near	22.51	27.06	23.40	19.26	19.52	20.50	25.02
Rear Far	27.45	27.38	27.98	29.04	25.27	20.33	33.76
Front Oblique	26.17	23.98	21.65	23.50	30.75	23.18	36.91
Rear Oblique	28.37	35.28	24.36	28.94	22.53	25.68	33.84
Average	24.5	25.8	23.9	25.7	22.0	20.1	29.3
Possible Responses:	480	80	80	80	80	80	80
Correct Responses:	442	74	72	79	71	73	73
Accuracy (%):	92.08	92.50	90.00	98.75	88.75	91.25	91.25

Table III.

Results of Unbalanced ANOVA

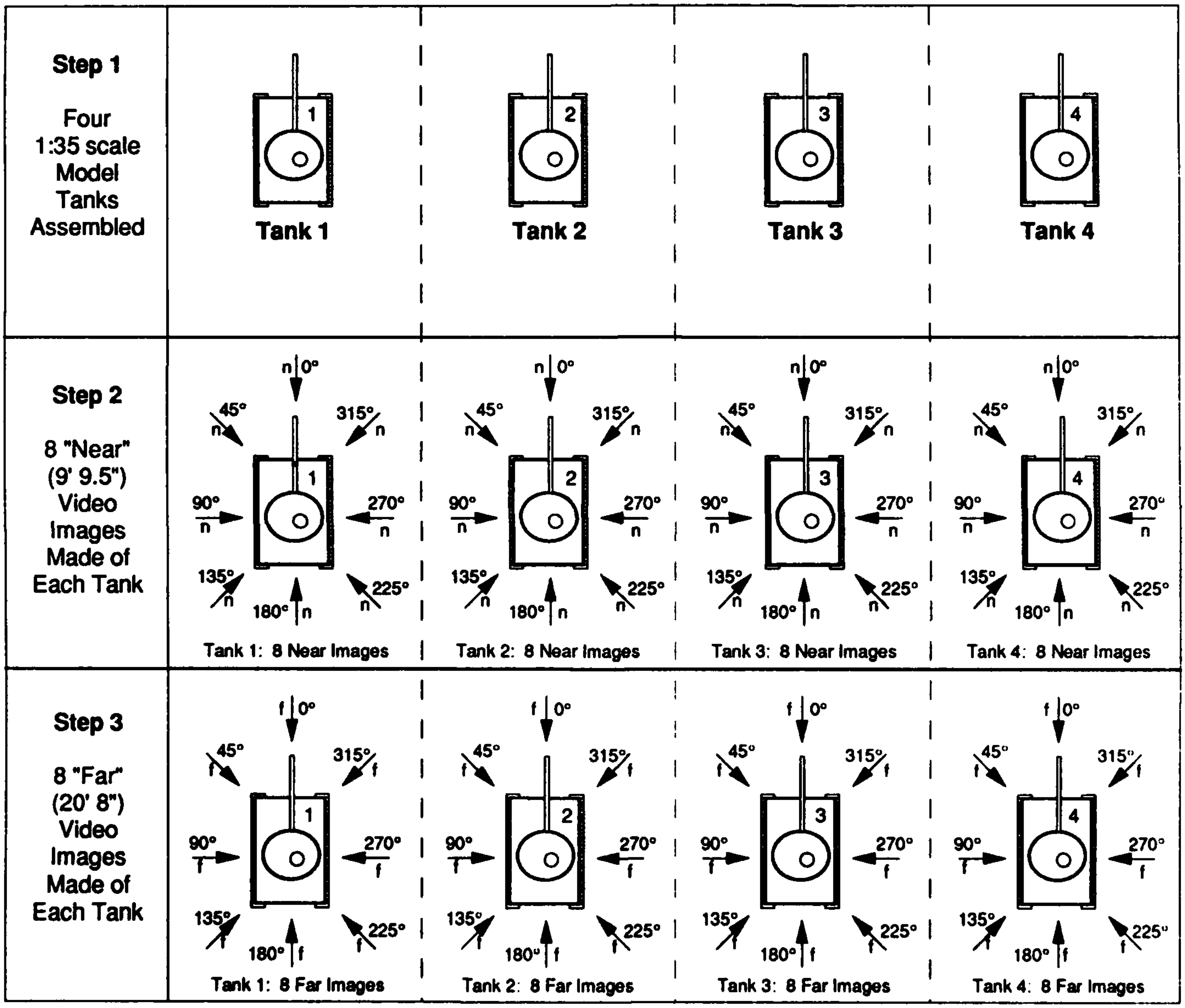
Number of observations: 883   Dependent Variable: Relative Contrast Threshold   Contrast Threshold Mean: 20.21

SOURCE	Degrees of Freedom	Sum of Squares	Mean Square	F-Value	Prob > F	R-Square
MODEL	71	35190	495.6	17.58	0.0	0.6061
ERROR	811	22870	28.2			

	Model Terms	Degrees of Freedom	Type ill Sums of Squares	F-Value	Pr > F
Main Effect	Filter Condition	1	16100	570.91	0.0
	Subject	5	5743	40.73	0.0001
	Tank	3	3142	37.14	0.0001
	Orientation	4	2422	21.47	0.0001
	Distance	1	568	20.13	0.0001
Interaction	Subject * Orientation	20	2230	3.95	0.0001
	Tank * Orientation	12	1502	12.01	0.0001
	Subject * Distance	5	1016	7.21	0.0001
	Subject * Tank	15	825	1.95	0.0163
	Orientation * Distance	2	677	12.01	0.0001
	Filter * Tank	3	479	5.67	0.0008

Figure 1

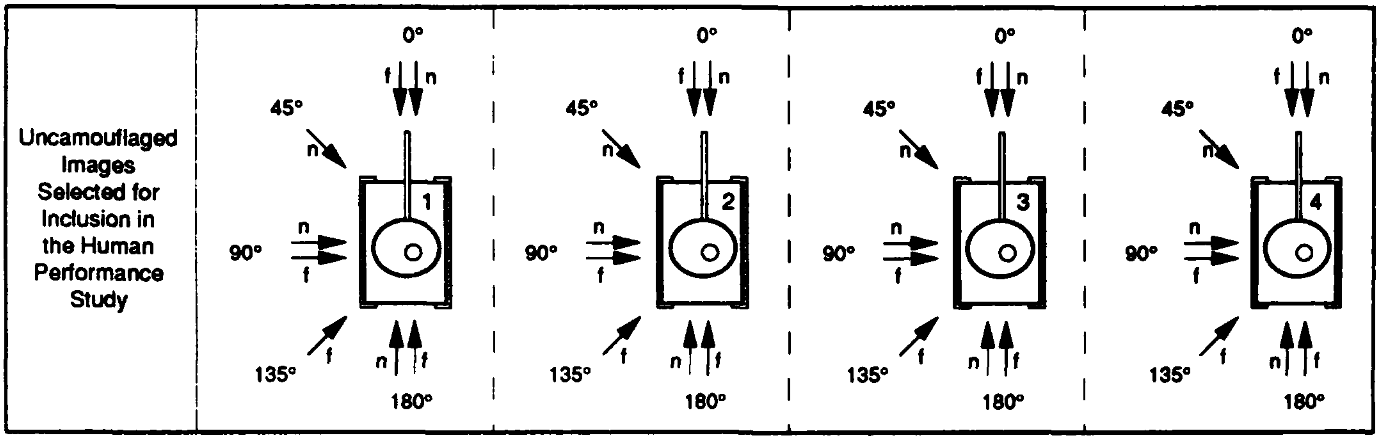
Summary of Development of Uncamouflaged Military-Relevant Images



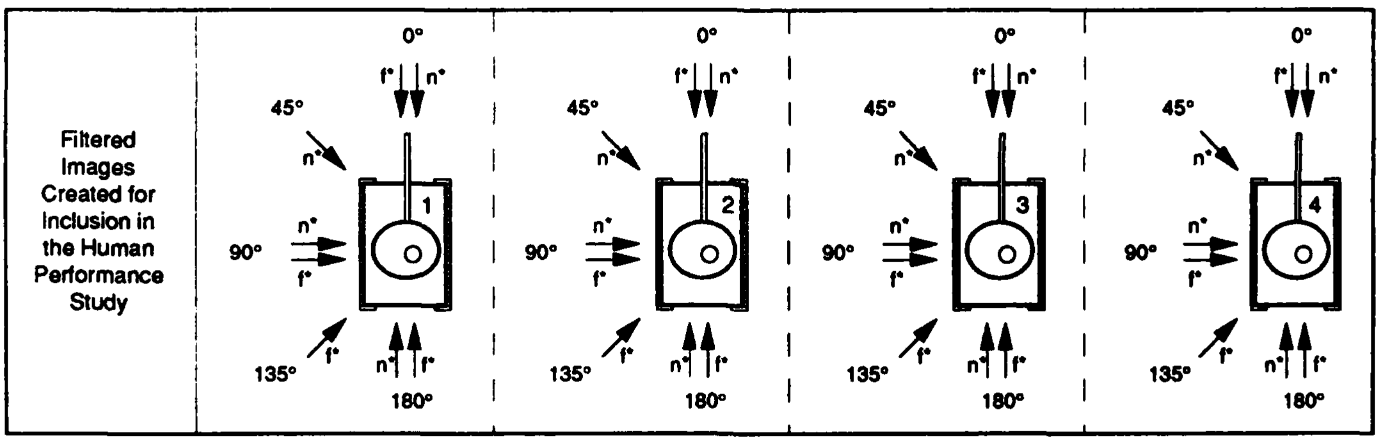
As seen in the Figure above, 8 near ("n") and 8 far ("f") video images were recorded of each model tank. This yielded 16 video images for each tank or 64 images altogether.

Figure 2.

Images Included in the Human Performance Study



Only 8 of the 16 images made of each tank were included in the human performance study.



Each of the 8 uncamouflaged images of each tank were "passed" through a filter to simulate the loss of contrast sensitivity associated with potential laser eye injuries. This procedure produced an additional 8 "filtered" (indicated by an asterisk) images for each tank, yielding 16 images for each tank. These 16 images are tabulated below.

	Unfiltered		Filtered	
	Near	Far	Near	Far
Front (0°)	X	X	X	X
Left-front Oblique (45°)	X		X	
Left (90°)	X	X	X	X
Left-rear Oblique (135°)	X		X	
Rear (180°)	X	X	X	X

Figure 3. Method of Conducting Each Trial

Initially, the image is presented with 0% of the contrast of the original images. In other words, the video screen appears white.

Gradually, the contrast in both images is increased. When the subject is able to identify the tank on either the right or the left, the trial is stopped. The tank recognized and the percent of the image contrast at which the subject recognized the target is recorded.

If the subject does not recognize either image at an intermediate level of contrast, the images will eventually contain 100% of the contrast contained in the original image.

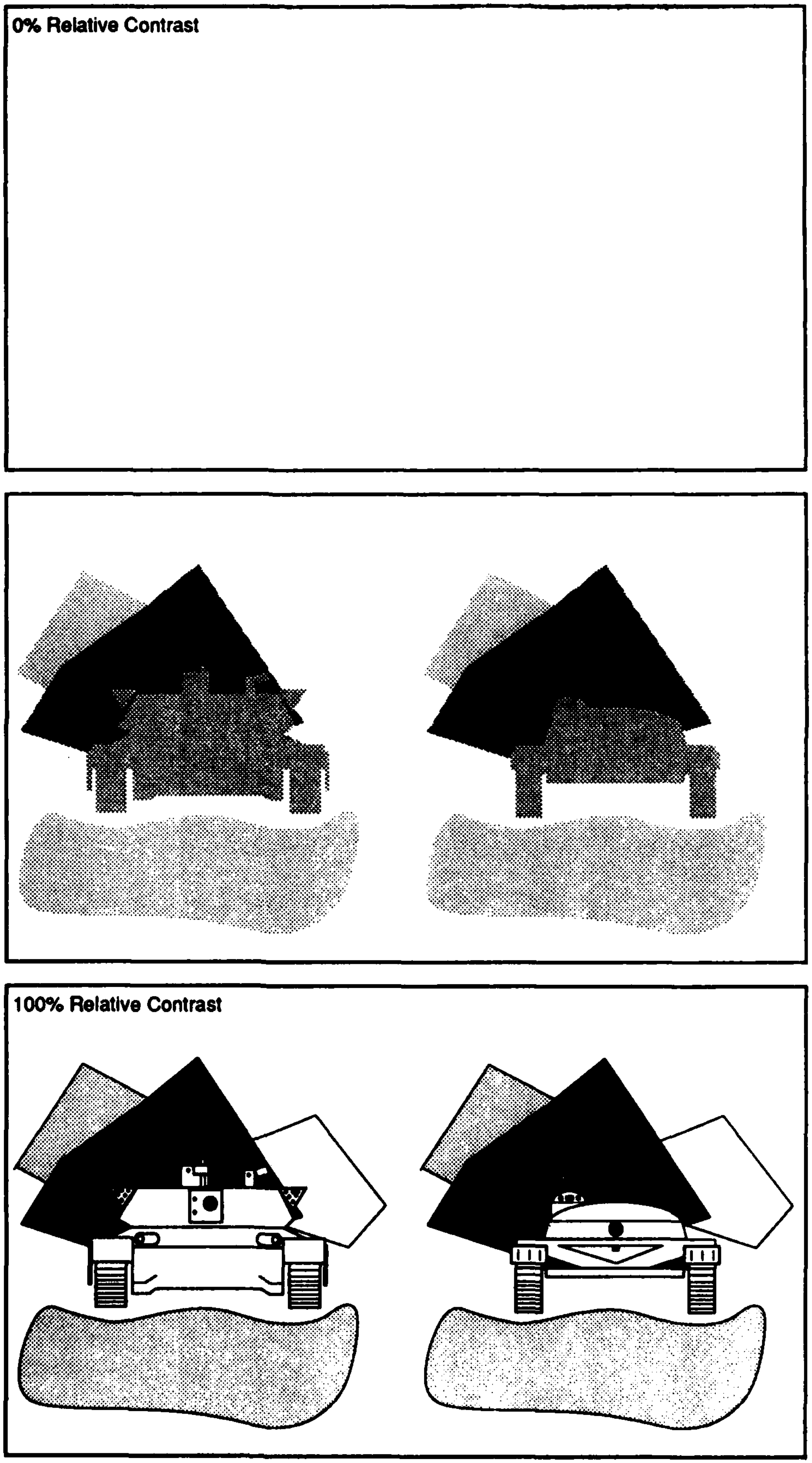


Figure 4.

Average Relative Contrast Threshold for Detection of Filtered and Unfiltered Images by View of Tank

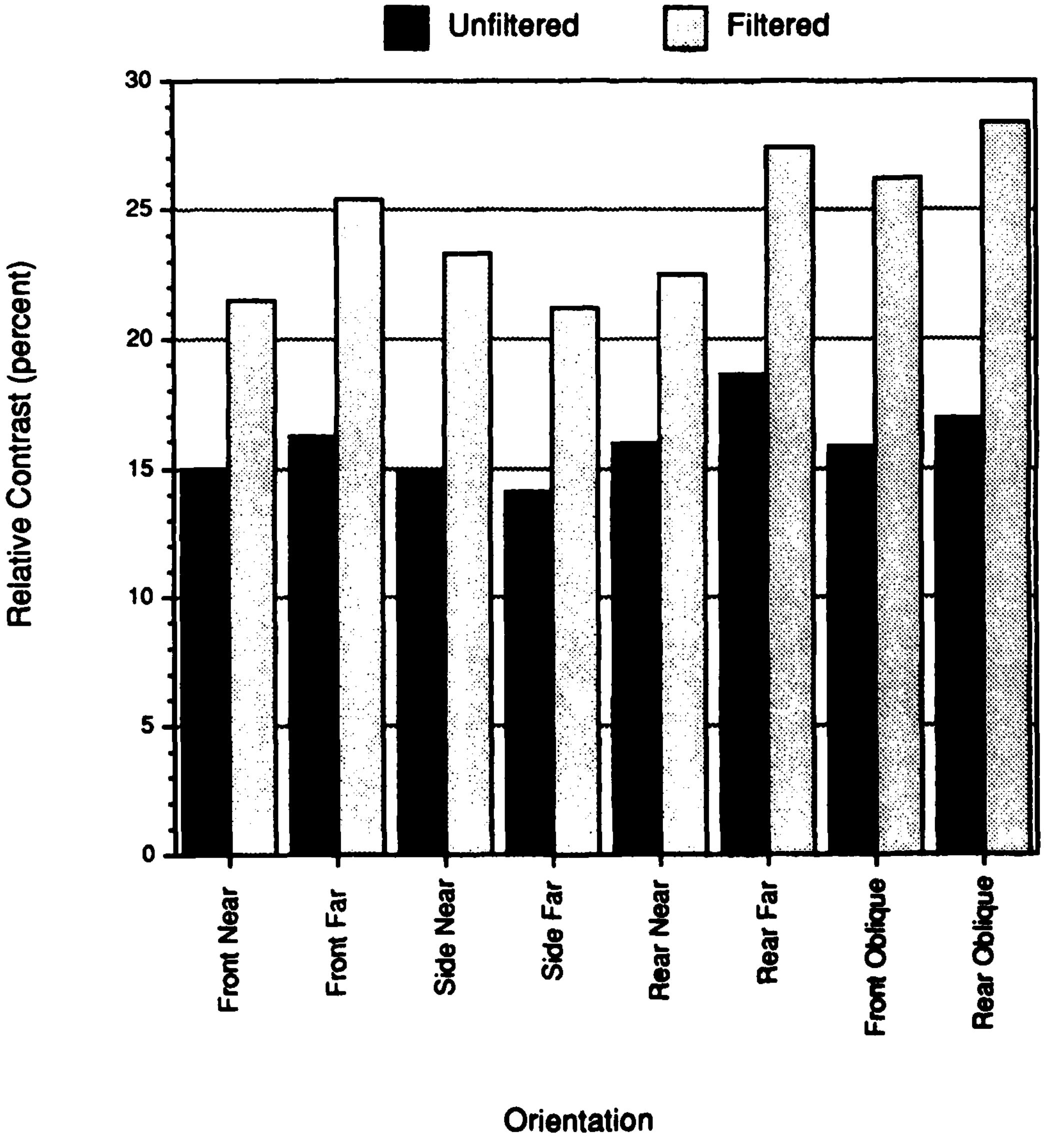
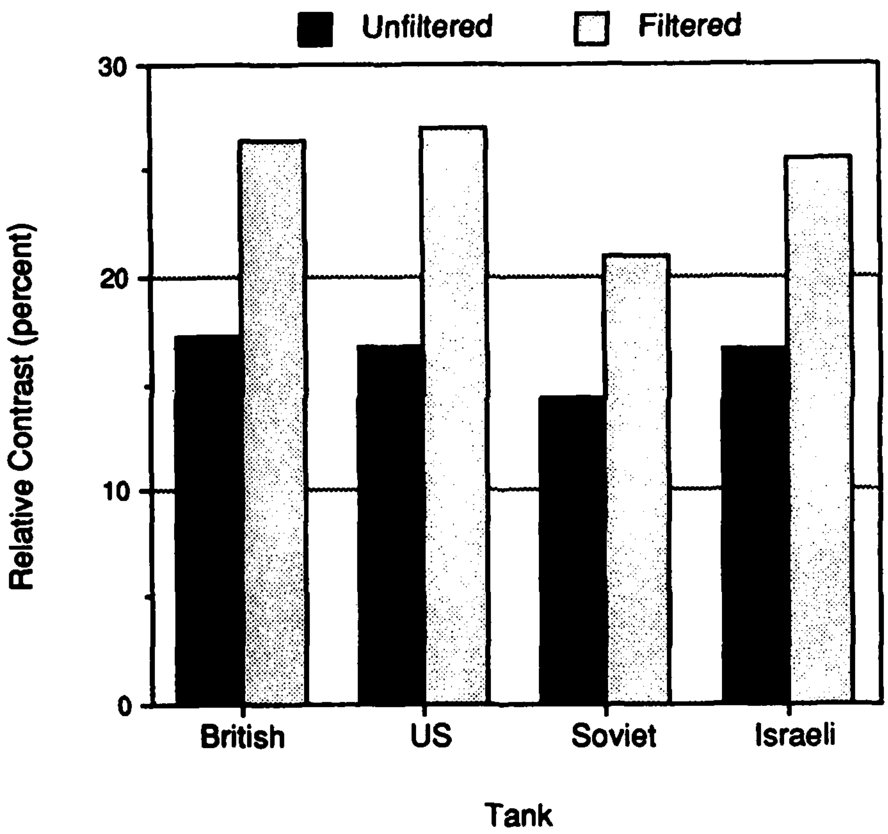


Figure 5.

Average Relative Contrast Threshold for Detection of Filtered and Unfiltered Images by Tank



Appendix

This appendix provides a detailed listing of all images created during the pilot study. The names correspond with the file names used on the Bernoulli disks.

<u>Uncamouflaged Images</u> (Total of 64 single tank images and 4 multiple tank images)

T11000.IMG	T21000.IMG	T31000.IMG	T41000.IMG
T11045.IMG	T21045.IMG	T31045.IMG	T41045.IMG
T11090.IMG	T21090.IMG	T31090.IMG	T41090.IMG
T11135.IMG	T21135.IMG	T31135.IMG	T41135.IMG
T11180.IMG	T21180.IMG	T31180.IMG	T41180.IMG
T11225.IMG	T21225.IMG	T31225.IMG	T41225.IMG
T11270.IMG	T21270.IMG	T31270.IMG	T41270.IMG
T11315.IMG	T21315.IMG	T31315.IMG	T41315.IMG
T12000.IMG	T22000.IMG	T32000.IMG	T42000.IMG
T12045.IMG	T22045.IMG	T32045.IMG	T42045.IMG
T12090.IMG	T22090.IMG	T32090.IMG	T42090.IMG
T12135.IMG	T22135.IMG	T32135.IMG	T42135.IMG
T12180.IMG	T22180.IMG	T32180.IMG	T42180.IMG
T12225.IMG	T22225.IMG	T32225.IMG	T42225.IMG
T12270.IMG	T22270.IMG	T32270.IMG	T42270.IMG
T12315.IMG	T22315.IMG	T32315.IMG	T42315.IMG

T1-4000.IMG - all 4 tanks shown simultaneously in one view from the front
T1-4090.IMG - all 4 tanks shown simultaneously in one view from the left
T1-4180.IMG - all 4 tanks shown simultaneously in one view from the rear
T1-4270.IMG - all 4 tanks shown simultaneously in one view from the right

Example: **T11000.IMG** - components are described serially below

"T1" refers to "Tank 1" where

Tank 1 (T1) =	British Challenger
Tank 2 (T2) =	US M1 Abrams
Tank 3 (T3) =	Soviet T-74
Tank 4 (T4) =	Israeli Merkava

"1" refers to the "near" distance where:

"1" =	Near Distance
"2" =	Far Distance

"000" refers to the front orientation where:

"000" =	Front orientation
"045" =	Left-front oblique orientation
"090" =	Left orientation
"135" =	Left-rear oblique orientation
"180" =	Rear orientation
"225" =	Right-rear oblique orientation
"270" =	Right orientation
"315" =	Right-front oblique orientation

".IMG" - means image (this suffix is required for the ISL software and is included at the end of all image file names)

Camouflaged Images

(Total of 32 camouflaged images - none were included in the study)

T1C1000.IMG	T2C1000.IMG	T3C1000.IMG	T4C1000.IMG
T1C1090.IMG	T2C1090.IMG	T3C1090.IMG	T4C1090.IMG
T1C1270.IMG	T2C1270.IMG	T3C1270.IMG	T4C1270.IMG
T1C2000.IMG	T2C2000.IMG	T3C2000.IMG	T4C2000.IMG
T1C2090.IMG	T2C2090.IMG	T3C2090.IMG	T4C2090.IMG
T1C2270.IMG	T2C2270.IMG	T3C2270.IMG	T4C2270.IMG
T1C3090.IMG	T2C3090.IMG	T3C3090.IMG	T4C3090.IMG
T1C3270.IMG	T2C3270.IMG	T3C31270.IMG	T4C3270.IMG

Example: **T1C1000.IMG** - components are described serially below

"T1" refers to "Tank 1" where

- Tank 1 (T1) = British Challenger
- Tank 2 (T2) = US M1 Abrams
- Tank 3 (T3) = Soviet T-74
- Tank 4 (T4) = Israeli Merkava

"C1" refers to the "Camouflage 1" where:

- "C1" = Center of tank partially obscured behind a single rock
- "C2" = Tank obscured partially by rocks
- "C3" = Tank in hull defilade position

"000" refers to the front orientation where:

- "000" = Front orientation
- "045" = Left-front oblique orientation
- "090" = Left orientation
- "135" = Left-rear oblique orientation
- "180" = Rear orientation
- "225" = Right-rear oblique orientation
- "270" = Right orientation
- "315" = Right-front oblique orientation

".IMG" - means image (this suffix is required for the ISL software and is included at the end of all image file names)

Performance Study Images

On this page are listed the images used in the performance testing portion of the pilot study. The Unfiltered Images are identical with certain of the Uncamouflaged Images previously enumerated. Their names were slightly modified by placing a "U" near the end to distinguish them from their "filtered" counterparts (which have an "F" instead of a "U"). For each unfiltered image, there is a filtered image which was created by "passing" the unfiltered image through an empirically derived acute laser injury filter (based on monkey experiments). All of the images listed below and the ISL software written to perform the study have been archived on a single Bernoulli disk.

T11000U.IMG	T21000U.IMG	T31000U.IMG	T41000U.IMG
T11045U.IMG	T21045U.IMG	T31045U.IMG	T41045U.IMG
T11090U.IMG	T21090U.IMG	T31090U.IMG	T41090U.IMG
T11135U.IMG	T21135U.IMG	T31135U.IMG	T41135U.IMG
T11180U.IMG	T21180U.IMG	T31180U.IMG	T41180U.IMG
T12000U.IMG	T22000U.IMG	T32000U.IMG	T42000U.IMG
T12090U.IMG	T22090U.IMG	T32090U.IMG	T42090U.IMG
T12180U.IMG	T22180U.IMG	T32180U.IMG	T42180U.IMG
T11000F.IMG	T21000F.IMG	T31000F.IMG	T41000F.IMG
T11045F.IMG	T21045F.IMG	T31045F.IMG	T41045F.IMG
T11090F.IMG	T21090F.IMG	T31090F.IMG	T41090F.IMG
T11135F.IMG	T21135F.IMG	T31135F.IMG	T41135F.IMG
T11180F.IMG	T21180F.IMG	T31180F.IMG	T41180F.IMG
T12000F.IMG	T22000F.IMG	T32000F.IMG	T42000F.IMG
T12090F.IMG	T22090F.IMG	T32090F.IMG	T42090F.IMG
T12180F.IMG	T22180F.IMG	T32180F.IMG	T42180F.IMG

Example: **T11000U.IMG** - components are described serially below

"T1" refers to "Tank 1" where	Tank 1 (T1) =	British Challenger
	Tank 2 (T2) =	US M1 Abrams
	Tank 3 (T3) =	Soviet T-74
	Tank 4 (T4) =	Israeli Merkava
"1" refers to the "near" distance where:	"1" =	Near Distance
	"2" =	Far Distance
"000" refers to the front orientation where:	"000" =	Front orientation
	"045" =	Left-front oblique orientation
	"090" =	Left orientation
	"135" =	Left-rear oblique orientation
	"180" =	Rear orientation
	"225" =	Right-rear oblique orientation
	"270" =	Right orientation
	"315" =	Right-front oblique orientation
"U" refers to the "unfiltered" image where:	"U" =	Unfiltered Image
	"F" =	Filtered Image

".IMG" - means image (this suffix is required for the ISL software and is included at the end of all image file names)

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